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**BUS SELECTOR DEVICE AND SEMICONDUCTOR INTEGRATED CIRCUIT SYSTEM
PROVIDED WITH THE DEVICE**

TECHNICAL FIELD

5 The present invention relates to a bus selector device which switches and selects among a plurality of buses connecting a plurality of chips, and also to a semiconductor integrated circuit system provided with the bus selector device.

BACKGROUND ART

10 With the rapid growth of an information society in recent years, there is an increase in demand for semiconductor circuit system which can process large amounts of data at high speed. Processing high volumes of data at high speed requires a number
15 of storage devices (memory devices) and high-speed data transmission with little loss.

20 From these viewpoints, one conventional approach is to connect a plurality of semiconductor memory devices such as DRAM devices in sequence; however, this solution increases the bus lengths between the memory controller which controls the devices and those arranged far from the controller. The long buses increase the delay in signal transmission, thereby damaging the high-speed data transmission. Moreover, the control of the plurality of memory devices to achieve
25 high-capacity semiconductor memory makes the buses between the

memory controller and the memory devices differ in length from each other. As a result, the speed in the signal transmission differs from one bus to another, making it impossible to compensate clock skew between the memory controller and each memory device. In high-speed clock operations, there may be cases where stable high-speed operations cannot be secured in the system.

In order to overcome this problem, conventional semiconductor integrated circuit systems have achieved high-speed data transmission, while compensating clock skew by reducing a delay in signal transmission as a result of shortening the bus length between the memory controller and each memory device. One such semiconductor integrated circuit system has been disclosed in U.S. Patent 5,408,129 by Rambus. In this system, the distance between the memory controller and each memory device is shortened as shown in Figures 17 (a) and 17 (b) to achieve high-speed stable operation, and when a large number of memory devices are connected, the memory controller to be installed in the master chip is provided with a plurality of channels to control the memory devices.

PROBLEMS TO BE SOLVED

However, in the above-mentioned conventional semiconductor integrated circuit systems, the serial connection of the memory devices increases the bus length between the memory controller

unit and the farthest memory device as more memory devices are arranged. This causes a delay in signal transmission between the memory controller unit and each of the nearest memory device and the farthest memory device. This delay makes it impossible to secure the stable high-speed operations of the system when high-frequency clock signals are transmitted. Moreover, the provision of the plurality of channels in the memory controller unit undesirably increases the number of pins in the unit, which increases the package size, thereby to raise the fabrication cost.

SUMMARY OF THE INVENTION

The object of the present invention is, in a semiconductor integrated circuit system, to realize a high-speed efficient control of the semiconductor memory devices by reducing variations in bus length among the devices without increasing the number of pins in the memory controller unit and the like.

In order to achieve the object, according to the present invention, a bus selector device which switches and selects among buses to semiconductor memory devices is arranged aside from the semiconductor memory devices so that a plurality of chips such as the semiconductor memory devices transmit and receive signals to and from each other.

The semiconductor integrated circuit system of the present invention is a semiconductor integrated circuit system having

a plurality of chips and making said plurality of chips transmit
and receive signals to and from each other, comprising a bus
selector device connected to said plurality of chips via a
plurality of buses, said bus selector device receiving
5 connection information among said plurality of chips and
selecting among connections of said plurality of buses in
accordance with the connection information.

Furthermore, the semiconductor integrated circuit system
of the present invention is a semiconductor integrated circuit
10 system having at least a master chip and a plurality of slave
chips, comprising: a bus selector device which is connected
to said master chip and said plurality of slave chips with a
plurality of buses and which selects among connections of said
plurality of buses, said bus selector device being arranged
15 substantially at a same distance from said plurality of slave
chips.

In the present invention, since the bus selector device
is arranged independent of the master chip, it reduces the number
of pins in the master chip. Furthermore, the bus selector device
20 is arranged at substantially the same distance from the slave
chips because the arrangement is free. Consequently, the bus
lengths between the master chip and the slave chips can be
approximately equal and short, which realizes the high-speed
data transmission among the master and slave chips and the storage
25 of high-volume data in the slave chips.

In the semiconductor integrated circuit system of the present invention, it is preferable that said bus selector device comprises switch means for switching among the connections of said plurality of buses, and determination means for determining the connection information among said plurality of chips received, and for outputting a switch signal in accordance with determination results to said switch means.

It is also preferable that said bus selector device comprises latch means for holding signals to be transmitted to or received from said plurality of chips to adjust timings of signal transmission and reception.

Said plurality of chips preferably include at least one master chip and a plurality of slave chips.

Said master chip may output the connection information among said plurality of chips to said bus selector device; and said master chip and said bus selector device may be connected to each other with a single bus, said single bus carrying the connection information among said plurality of chips.

It is also possible that said master chip outputs the connection information among said plurality of chips to said bus selector device; and said master chip and said bus selector device are connected to each other with two or more buses, one of said two or more buses carrying the connection information among said plurality of chips.

Said two or more buses may include a command bus which is

also used as a connection information bus to carry the connection information among said plurality of chips.

Said one of said two or more buses to carry the connection information among said plurality of chips may be a specifically designed connection information bus.

The connection information among said plurality of chips may be composed of a packet.

It is preferable that said bus selector device is arranged substantially at a same distance from said master chip and said plurality of slave chips.

Said plurality of slave chips may be memory.

The bus selector device of the present invention, which is connected to a plurality of chips with a plurality of buses and selects among connections of said plurality of buses, comprises: switch means for switching among the connections of said plurality of buses; and determination means for receiving and determining connection information among said plurality of chips, and for outputting a switch signal in accordance with determination results to said switch means.

The bus selector device of the present invention preferably further comprises: control signal input means for receiving a control signal from one of said plurality of chips for another chip; and control signal output means for outputting said control signal to at least one of said plurality of chips through one of said plurality of buses selected by switching of said switch

means.

Furthermore, the bus selector device of the present invention preferably comprises: data input means for receiving data from one of said plurality of chips; and data output means for outputting said data to at least one of said plurality of chips through one of said plurality of buses selected by switching of said switch means.

It is also preferable that the bus selector device of the present invention further comprises a plurality of internal buses connected to said plurality of buses, said plurality of internal buses each being provided with latch means.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the entire structure of the semiconductor integrated circuit system of the first embodiment of the present invention.

Figure 2 is a diagram showing the structure of the determination circuit provided in the semiconductor integrated circuit system of the first embodiment.

Figures 3 (a), 3(b) and 3(c) respectively show the structure of the selector circuit, the structure of the latch circuit, and determination results for entered commands in the semiconductor integrated circuit system of the first embodiment.

Figure 4 is a diagram showing an example of each timing

of entering commands and outputting data in the semiconductor integrated circuit system of the first embodiment.

Figure 5 is a diagram showing the structure of the command packet used in the semiconductor integrated circuit system of the first embodiment.

Figure 6 is a diagram showing an example of each timing of entering commands, switching buses and outputting data in the semiconductor integrated circuit system of the first embodiment.

Figure 7 is a diagram showing another example of these timings.

Figure 8 is a block diagram showing the entire structure of the semiconductor integrated circuit system of the second embodiment of the present invention.

Figure 9 is a diagram showing the structure of the selection circuit provided in the semiconductor integrated circuit system of the second embodiment.

Figure 10 is a diagram showing the structure of the determination circuit provided in the semiconductor integrated circuit system of the second embodiment.

Figures 11 (a) and 11(b) respectively show the structure of the command bus selector circuit and the structure of the data bus selector circuit provided in the semiconductor integrated circuit system of the second embodiment.

Figure 12 is a diagram showing the structure of the command

packet used in the semiconductor integrated circuit system of the second embodiment.

Figure 13 is a diagram showing determination results for the entering of the command packet.

Figure 14 is a block diagram showing the entire structure of the semiconductor integrated circuit system of the third embodiment of the present invention.

Figure 15 is a diagram showing the structure of the command packet used in the semiconductor integrated circuit system of the third embodiment.

Figure 16 is a diagram showing an example of each timing of entering commands, switching buses and outputting data in the semiconductor integrated circuit system of the second embodiment.

Figure 17 is a diagram showing an example of each timing of entering commands, switching buses and outputting data in the semiconductor integrated circuit system of the third embodiment.

Figure 18 is a diagram showing a modified example of the selector circuit provided in the semiconductor integrated circuit system of the present invention.

Figure 19 is a diagram showing another example of each timing of entering commands, switching buses and outputting data in the semiconductor integrated circuit system of the third embodiment.

Figure 20 is a block diagram showing the entire structure of the semiconductor integrated circuit system of the fourth embodiment of the present invention.

Figures 21 (a) and 21 (b) are diagrams showing the entire rough structures of the conventional semiconductor integrated circuit system.

BEST MODE FOR CARRYING OUT THE INVENTION

EMBODIMENT 1

Figure 1 shows the semiconductor integrated circuit system 110 of the first embodiment. The system 110 in the present embodiment comprises a CPU as master chip 1, and first, second and third DRAM chips as slave chips 2a, 2b and 2c.

In the system 110, a bus selector device 3 is connected to the master chip 1 and slave chips 2a, 2b and 2c via buses (transmission paths) B, Ba, Bb and Bc, respectively. The master chip 1 comprises a memory controller 1a which transmits and receives data to and from the slave chips 2a to 2c. The memory controller 1a outputs commands to control the slave chips 2a to 2c by a packet mode. The single bus (transmission path) B connecting the bus selector device 3 and the master chip 1 has a width of plural bits (for example, 8 bits) to carry commands and data. The buses Ba to Bc respectively connecting the bus selector device 3 and the slave chips 2a to 2c also carry commands and data. It can be appropriately determined whether the bus

selector device 3 is integrated into one chip with the master chip 1 or without the chip 1.

The bus selector device 3 comprises four input/output units 6 and 6a to 6c, a determination circuit (determination means) 7, a selector circuit (selector means) 8, latch circuits (latch means) 9a to 9c and clock phase adjustment circuit (DLL) 10. The input/output units 6 and 6a to 6c transmit and receive commands and data to and from the master chip 1 and the slave chips 2a to 2c via the buses B and Ba to Bc, respectively. The determination circuit 7 receives a command from the master chip 1 through the input/output unit 6, determines which of the slave chips 2a to 2c the command is bound for from the ID information in the command and outputs the determination results. The selector circuit 8 receives the determination results and switches the bus connections between the master chip 1 and the slave chips 2a to 2c, based on the determination results. The latch circuits 9a to 9c arranged on respective internal buses IB and IBa to IBc in the bus selector device 3 latch commands outputted from the master chip 1 and data outputted from the slave chips 2a to 2c. The clock phase adjustment circuit 10 generates a clock CLK2.

The selector circuit 8 is arranged on a point of intersection of the internal buses IB and IBa to IBc which connect the four input/output unit 6 and 6a to 6c, that is, on a point of intersection of the buses B and Ba to Bc which connect the master

chip 1 and the slave chips 2a to 2c so as to reduce the lengths of the transmission paths between the master chip 1 and the slave chips 2a to 2c. The selector circuit 8 has a decode function to select one from among the buses B and Ba to Bc based on a signal received from the determination circuit 7 via the bus S, and a latch function to hold the selection of the bus until the next bus is selected. Figure 3 (a) shows the rough structure of the selector circuit 8, which includes selector switches SWa, SWb and SWc corresponding to the slave chips 2a, 2b and 2c, respectively. The selector circuit 8 receives a selector signal Sa, Sb or Sc from the determination circuit 7 and activates the selector switch SWa, SWb or SWc on the bus between the master chip 1 and the selected slave chip to make these chips transmit commands and data to each other. Changing the contents of the selector signals Sa, Sb and Sc makes it possible to activate more than one selector switch at the same time, thereby to transmit commands to more than one slave chip at the same time.

Figure 2 shows the internal structure of the determination circuit 7. As shown in the structure, the determination circuit 7 comprises an input unit 7a which receives commands from the bus B, a determination unit 7b which analyzes the received commands, a latch circuit 7c which holds the determination results of the determination unit 7b until it receives the next determination results, and an output unit 7b which outputs the determination results transferred from the latch circuit 7c.

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The behavior of the determination circuit 7 will be roughly described as follows. The determination unit 7b generates the selector signal Sa, Sb or Sc activating the selector switch SWa, SWb or SWc, respectively, from the two higher order bits of a packet-mode command that the input unit 7a has received. To be more specific, as shown in Figure 3 (c), the determination unit 7b decodes the two higher order bits "01", "10" and "11" of the command so as to activate the respective selector switches SWa, SWb and SWc which correspond to the slave chips 2a, 2b and 2c by generating the respective selector signals Sa, Sb and Sc. The selector signal Sa, Sb or Sc generated in the determination unit 7b is maintained as it is in the latch circuit 7c until the next selector signal is generated. The output unit 7d receives the selector signal Sa, Sb or Sc from the latch circuit 7c and outputs it to the selector circuit 8. The determination circuit 7 can be arranged either independently as shown in Figure 1 or inside the selector circuit 8. The selector signals Sa, Sb and Sc generated in the determination unit 7b can be transmitted either via the transmission paths having plural bits as shown in Figure 2, or via fewer transmission paths by serial-parallel converting the signals.

The latch circuits 9a to 9c are arranged on the internal buses B1a to B1c, which are between the selector circuit 8 and the input/output units 6a to 6c, respectively, and have a bi-directional structure to receive commands from the master

chip 1 via the selector circuit 8 and to output them to the slave chips 2a to 2c, and also to receive data from the slave chips 2a to 2c and to output them to the selector circuit 8. The latch circuits 9a to 9c include respective delay circuits (not shown) to delay the selector signals Sa to Sc outputted on the bus S from the determination circuit 7 by a predetermined time period. Furthermore, as shown in Figure 3 (b), the latch circuits 9a to 9c, which can be composed of clocked inverters (only unilateral latch circuits are shown), receive a clock CLK2 from the clock phase adjustment circuit 10 to temporarily hold entered commands or data before outputting them, based on the clock CLK2 and the delayed selector signal.

When the commands or the data have variations in output timing, the clock phase adjustment circuit 10 adjusts the timings. In addition to the receipt of the clock CLK1 via the clock line 5a, the clock phase adjustment circuit 10 gets feedback of the clock CLK2 via the clock line 5b, analyzes the status of the clock CLK2 to adjust the phase of the clock CLK1 based on the analysis, and outputs the phase-adjusted clock CLK1 as the clock CLK2. The clock CLK2 is used to determine the operating timings of the latch circuits 9a to 9c, and to adjust the timings to output commands from the master chip 1 to the slave chips 2a to 2c.

The latch circuits 9a to 9c are controlled by the clock CLK2 outputted from the clock phase adjustment circuit 10 and

the selector signals Sa, Sb and Sc from the determination circuit 7." When the selector signal is high, the latch circuits 9a to 9c capture signals transmitted from the selector circuit 8 or the slave chips 2a to 2c. This approach can both activate the selector circuit 8 and adjust the timing of signal transmission, which enables the control of the signals between the selector circuit 8 and the slave chips 2a to 2c. The outputs of the latch circuits 9a to 9c are transmitted either to the input/output units 6a to 6c or to the selector circuit 8. The latch circuits 9a to 9c, which could perform bi-directional transmission of signals, may be provided with the bi-directional latch feature either by a single circuit or by a combination of unilateral latch circuits in reverse directions.

The first, second and third DRAM chips, which are the slave chips 2a to 2c, could be provided with a clock phase adjustment function like DDR DRAM or SDRAM, or a function to use the clock lines as data clocks by folding them. With these functions, the DRAM chips can output data without adjusting the timing with the clock CLK1.

The signal (control command), which is transmitted from the master chip 1 not only to the determination circuit 7 but also to the selector circuit 8, is also transmitted to the previously-selected slave chip via the bus selected before the transmission of the control command. Therefore, the slave chips 2a to 2c are provided with respective determination circuits

19a to 19c which do not recognize a command whose first bit is "0" as a command. When the first bit of the command is "1", the determination circuits 19a to 19c recognize the command as the command for the slave chips 2a to 2c.

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Figure 5 shows an example of the structure of the command packet outputted from the master chip 1. In the structure, the command packet is composed of eight bits. In the command C1xx, the first bit has destination determination information; the second and third bits have the ID information of the slave chip 2a, 2b or 2c; and the fourth to eighth bits have respective values but no meaning as information. The destination determination information indicates whether the signal is bound for the determination circuit 7 or for the selector circuit 8. The first bit is "0" when the signal is bound for the determination circuit 7, and is "1" when for the selector circuit 8. The ID information indicates which of the three slave chips 2a to 2c should be selected, and can be as shown in Figure 3 (c), depending on the combinations of the values of the second bit A and the third bit B. In the command Cxx, the first bit has destination determination information, the second bit has information indicating which of data reading and data writing should be performed, and the third to eighth bits have the address information of the data to be read or written.

The number of the higher order bits of the command having

the ID information could be larger than 3 in accordance with the number of slave chips or with the way of connecting the buses. In that case, more than one slave chip can be selected to control more slave chips (DRAM chips). In the present embodiment, one slave chip is selected from among the three slave chips 2a to 2c; however, increasing the number of the higher order bits of the command containing the ID information enables the concurrent transmission of two or more commands to two or more slave chips.

The behavior of the semiconductor integrated circuit system 110 will be described in detail as follows.

Figure 4 is a schematic diagram showing the data readout timing as an example of the behavior of the semiconductor integrated circuit system 110 shown in Figure 1. For example, the master chip (CPU) 1 transmits a command to the slave chip (DRAM chip) 2a to read data therefrom. Assuming that there is an eight-bit bus to carry commands and data, the command from the master chip 1 includes the selection information (command C_{Ixx} containing the ID information of a slave chip) to select one bus from among the buses B_a to B_c to the slave chips 2a to 2c as the connection information among the chips 1 and 2a to 2c, and further includes the readout address (command C_{xx} not containing the ID information of the slave chip) of the slave chip 2a. This command is transmitted by the packet mode in synchronization with the clock CLK₁ (synchronous with

the rise and fall of the clock) as shown in Figure 4. In Figure 4, the bus B indicates the propagation of signals on the bus B. As a signal propagating on the bus B, the master chip 1 first outputs the command C_{Ixx}, and then transmits a command (readout instruction) to the target slave chip 2a, which is to be executed therein. After a predetermined process time has passed, the slave chip 2a transmits the data D_{xx} to the master chip 1.

The command signal C_{Ixx} containing the ID information and the command C_{xx} such as a readout address can be transmitted in sequence as shown in Figure 4 (a). Alternatively, it is possible as shown in Figure 4 (b) that the command C_{Ixx} is transmitted first and the command C_{xx} is transmitted in a later time.

The following is a description for one or more of the slave chips 2a to 2c to receive a command from the master chip 1, to execute the command and to output data obtained by the execution (readout process or the like) to the master chip 1 or the remaining ones of the slave chips 2a to 2c.

- 1) When the slave chip 2a outputs data to the master chip 1

After the execution of the command from the master chip 1 to the slave chip 2a, data is transmitted from the slave chip 2a to the input/output unit 6a and further to the latch circuit 9a. The data entered in the latch circuit 9a is controlled

by the clock CLK2 and the selector signal Sa to be outputted to the selector circuit 8. As described above, the latch circuit 9a captures data in accordance with the entry of the selector signal Sa (high) so as to activate the switch SWa and to adjust the timing of data transfer. In order to activate the switch SWa, the master chip 1 outputs a command packet containing the ID information of the switch SWa to the determination circuit 7, which analyzes the command packet and outputs the selector signal Sa for the switch SWa to the selector circuit 8. The selector signal Sa is also outputted to the latch circuit 9a at the same time. The data read out in the slave chip 2a is transferred from the selector circuit 8 to the input/output unit 6, and further transmitted to the master chip 1.

2) When the slave chips 2a to 2c output data to the master chip 1

The following is a description of the case where the master chip 1 transmits commands in sequence to the slave chips 2a, 2b and 2c as shown in Figure 6. In Figure 6, the bus B indicates the statuses of signals propagating on the bus B.

First of all, at timing T1, the master chip 1 transmits the command C1a1 containing the ID information of the slave chip 2a to establish a transmission path to the slave chip 2a. At timing T3, the master chip 1 transmits a command (for example, readout instruction) Ca1 to the slave chip 2a. At timing T4, the master chip 1 transmits the command C1b1 containing the

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ID information of the slave chip 2b to disconnect the transmission path to the slave chip 2a, and establishes a transmission path to the slave chip 2b. At timing T6, the master chip 1 transmits the command Cb1 to the slave chip 2b. At timings T7 to T9, the same operations follow with the slave chip 2c. While the operations at timing T4 to T9 are being performed, at timing T5, the slave chip 2a outputs the data Da1 obtained by the execution of the command Ca1 to the latch circuit 9a where the data Da1 is temporarily held by a latch control signal C9a.

At timing T10, the master chip 1 transmits the command C1a2 containing the ID information of the slave chip 2a to establish a transmission path to the slave chip 2a. At this moment, the determination circuit 7 also transmits the selector signal Sa to the latch circuit 9a, so that at timing T11, the data Da1 held in the latch circuit 9a is outputted to the selector circuit 8. Later, the selector circuit 8 transmits the data Da1 to the master chip 1 via the bus B. In a state of establishment of the transmission path to the slave chip 2a, at timing T12, the master chip 1 outputs the next command Ca2 to the slave chip 2a. The same operations follow with the other slave chips 2b and 2c at the timings shown in Figure 6.

As a result of the behavior described hereinbefore, the master chip 1 and the slave chips 2a to 2c can transmit and receive commands and data to and from each other so as to control the slave chips 2a to 2c. Adjusting the transmission timings

of the commands and the data can prevent the coexistence of a command and data on the same bus at the same timing.

Figure 7 shows the timings when the master chip 1 transmits commands to the slave chips 2a to 2c at random. The bus B in Figure 7 indicates the statuses of signals propagating on the bus B. In Figure 7, the master chip 1 transmits the commands in order of slave chips 2a, 2c, 2b, 2c, 2a, 2b, 2a and 2c.

To transmit the command Cal to the slave chip 2a, at timing T1, the master chip 1 outputs the command C1a1 containing the ID information of the slave chip 2a to activate the switch SWa, thereby to establish a transmission path to the slave chip 2a. Later, the master chip 1 transmits the command (readout instruction) Cal to the slave chip 2a. The slave chip 2a receives the command Cal, executes it and output the data Dal. The switch SWa keeps its state until the data Dal is transmitted to the master chip 1. After the receipt of the data Dal, the master chip 1 outputs the command C1c1 containing the ID information of the slave chip 2c to disconnect the transmission path to the slave chip 2a. The master chip 1 then establishes a transmission path to the slave chip 2c, and at timing T6, transmits the command (readout instruction) Cc1 to the slave chip 2c. The same operations are performed hereinafter.

As a result of the behavior described hereinbefore, the master chip 1 can transmit and receive signals to and from the

slave chips 2a to 2c at random so as to perform random control of the slave chips 2a to 2c. Since the master chip 1 outputs a number of commands while the transmission path is established, commands and data can be transmitted in sequence.

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Although it is not described in the present embodiment, changing the ID information of the slave chips 2a to 2c to be transmitted to the determination circuit 7 makes it possible not only to connect the master chip 1 and the slave chips 2a to 2c but also to connect the slave chips 2a to 2c themselves. For example, in the case where the slave chips 2a to 2c have a calculation function, the master chip 1 transmits a command packet containing the ID information of the slave chip 2a to establish a transmission path to the slave chip 2a, and then transmits a command to the slave chip 2a. Later, the master chip 1 transmits a command packet containing the ID information connecting the two slave chips 2a and 2b so as to establish a transmission path between these slave chips 2a and 2b. As a result, the slave chip 2a can execute the command transmitted from the master chip 1 and transfer the data obtained by the execution to the slave chip 2b via the established transmission path so that the slave chip 2b can perform another process, based on the data.

The selector circuit 8 could be provided to each bit of the buses B and Ba to Bc each consisting of plural bits. Signals

can be transmitted between the master chip 1 and the slave chips 2a to 2c or between the slave chips 2a to 2c themselves concurrently by defining the ID information of the slave chips 2a to 2c contained in the command packet as follows. For example, the first bit, the second bit and the third bit of the bus B to the master chip 1 can be respectively connected with the first bit of the bus Ba for the slave chip 2a; the second bit of the bus Bb for the slave chip 2b; and the third bit of the bus Bc for the slave chip 2c.

EMBODIMENT 2

Figure 8 shows the semiconductor integrated circuit system 110 of the second embodiment of the present invention. While the first embodiment uses the single buses B and Ba to Bc having a predetermined bit width in connecting the chips 1 and 2a to 2c with the bus selector device 3, the present embodiment uses two buses: a data bus and a command bus, and the switching information of the buses is transmitted via the command bus to the bus selector device 3.

In the semiconductor integrated circuit system 110 shown in Figure 8, the bus selector device 3a is surrounded by four chips 1, 2a, 2b and 2c arranged at the same distance from the device 3a. This arrangement is identical to that of the semiconductor integrated circuit system 110 of the first embodiment. The master chip 1 is connected to the bus selector

device 3a via the two buses, that is, the command bus CB and the data bus DB each having a width of plural bits (n bits) to carry commands and data, respectively. The slave chips 2a to 2c are also connected to the bus selector device 3a via command buses CBa to CBc and data buses DBa to DBc to carry commands and data. The command bus CB which connects the master chip 1 and the bus selector device 3a is also used as a connection information bus to carry connection information indicating the connection of the chips 1 and 2a to 2c.

In Figure 8, the bus selector device 3a comprises an input/output unit 4 which transmits and receives commands to and from the master chip 1 via the command bus CB that is a transmission path having a width of plural bits; a destination selection circuit (destination selection means) 12 which receives a command from the input/output unit 4, analyzes the command to determine whether it contains the connection information among the slave chips 2a to 2c and selects the destination in accordance with the analysis results; a determination circuit (determination means) 13 which receives the command from the destination selection circuit 12, analyzes the connection information among the slave chip 2a to 2c and outputs the analysis results (selector signal); a command bus selector circuit 14 which is arranged on a point of intersection of the command buses CB and CBa to CBc connecting the master chip 1 with the slave chips 2a to 2c; and a data bus selector

circuit 15 which is arranged on a point of intersection of the data buses DB and DBa to DBc connecting the master chip 1 with the slave chips 2a to 2c. Upon receipt of the analysis results from the determination circuit 13, the command bus selector circuit 14 and the data bus selector circuit 15 switch and select among the command buses and the data buses, respectively, between the master chip 1 and the slave chips 2a to 2c or between the slave chips 2a to 2c themselves.

The bus selector device 3a further comprises input/output units (control signal input means and control signal output means) 6, 8 and 10 for the inputting and outputting commands, and input/output units (data input means and data output means) 5, 7, 9 and 11 for the inputting and outputting of data. The input/output units 6, 8 and 10 receive commands from the master chip 1 through the command bus selector circuit 14 and output them to the slave chips 2a to 2c via the command buses CBa to CBc. The input/output units 7, 9 and 11 transmit and receive data, which have been transmitted to or received from the slave chips 2a to 2c, to and from the data bus selector circuit 15 via the data buses DBa to DBc. The input/output unit 5 receives data from the slave chips 2a to 2c through the data bus selector circuit 15 and outputs them to the master chip 1 via the data bus DB.

As described above, the command bus selector circuit 14 and the data bus selector circuit 15 are arranged on a point

of intersection of the command buses CB and CBa to CBc and on a point of intersection of the data buses DB and DBa to DBc connecting the master chip 1 and the slave chips 2a to 2c; however, these circuit 14 and 15 could be arranged differently. For example, in addition to the command bus selector circuit 14 and the data bus selector circuit 15, it is possible to arrange additional bus selector circuits on a point of intersection of the command buses CB, CBb and the data buses DBa, DBc and on a point of intersection of the command buses CBa, CBc and the data buses DB, DBb. In this structure, data outputted from the slave chip 2a via the data bus DBa can be entered to the slave chip 2b as a command via the command bus CBb, thus enabling the chips 1 and 2a to 2c share commands and data with each other. The numerical structure of the master chip and the slave chips in the semiconductor integrated circuit system could be appropriately determined.

As shown in Figure 9, the destination selection circuit 12 shown in Figure 8 comprises an input unit 121 which receives commands from the input/output unit 4; an analysis unit 122 which analyzes the commands to determine whether the commands contain the connection information among the slave chips 2a to 2c; a selection unit 123 which selects between the determination circuit 13 and the command bus selector circuit 14 shown in Figure 8 to transmit the commands in accordance with the analysis results; and output units 124, 125 which output

commands respectively to the determination circuit 13 and the command bus selector circuit 14.

As shown in Figure 10, the determination circuit 13 shown in Figure 8 comprises an input unit 131 which receives commands from the destination selection circuit 12 shown in Figure 8, a determination unit 132 which analyzes the commands and generates selector signals selecting at least one of the command bus selector circuit 14 and the data bus selector circuit 15; a latch unit 133 composed of two latch circuits 133a, 133b which hold the statuses of the selector signals received from the determination unit 132 until the next selector signals are entered; and output units 134a, 134b which output the selector signals received from the latch circuits 133a, 133b of the latch unit 133 to the command bus selector circuit 14 and the data bus circuit 15, respectively.

The determination unit 132 and the latch unit 133 are connected with each other via control lines 135a and 135b. Besides transmitting the selector signals bound for the command bus selector circuit 14 and the data bus selector circuit 15, the control lines 135a and 135b carry control commands which control the latch circuits 133a and 133b. The latch circuits 133a and 133b are controlled by the control commands from the determination unit 132. For example, when the control lines 135a and 135b receive control commands "0" (low) and "1" (high), respectively, the latch circuit 133a keeps the status of the

previous signal without receiving the selector signal from the determination circuit 132, while the latch circuit 133b receives the selector signal and transfers it to the data bus selector circuit 15. When the control lines 135a and 135b both receive control commands "1", the latch circuits 133 and 133b output entered selector signals to the command bus circuit 14 and the data bus circuit 15, respectively. The control commands can be used to select the destination of the selector signals and to adjust their timings.

The command bus selector circuit 14 and the data bus selector circuit 15 are arranged on a point of intersection of the command buses CB and CBa to CBc and on a point of intersection of the data buses DB, DBa to DBc as shown in Figure 8. These circuits 14 and 15 comprise selector switches SWa to SWf shown in Figures 11 (a) and 11 (b) which are arranged respectively on the command buses CB and CBa to CBc and the data buses DB and DBa to DBc connecting the master chip 1 and the slave chips 2a to 2c. The selector switches SWa to SWf are switched by the selector signals transmitted from the determination unit 132.

Before the description of the behavior of the semiconductor integrated circuit system 110, the structure of the command packet involved in the behavior of the system 110 will be described as follows.

Figure 12 shows the rough structure of the command packet used in the present embodiment, and Figure 13 shows the

determination results of the determination circuit 13 for the entered commands shown in Figure 12. Assume that each of the command buses CB and CBa to CBc and the data buses DB and DBa to DBc which carry commands and data has a bus width of 7 bits.

5 The bus width could be changed if necessary.

10 In the command packet shown in Figure 12, the bus selection control command C_{Ixx} consists of the first bit having destination information indicating which is the destination of the command between the command bus selector circuit 14 and the determination circuit 13; the second and third bits having information indicating which should be controlled between the command bus selector circuit 14 and the data bus selector circuit 15; the fourth and fifth bits having control information for the command bus selector circuit 14; and the sixth and seventh bits having control information for the data bus selector circuit 15. The slave control command C_{xx} consists of the first bit having the destination information; the second bit having operating information indicating either data reading or data writing; and the third through seventh bits having address information of the data to be either read or written. The data D_{xx} consisting of the first bit having the destination information; the second bit having operating information indicating either data reading or data writing; and the third to seventh bits having data to be written. The values of these bits and the determination results of the determination circuit 13 are shown in Figure

15

20

25

13.

The destination selection circuit 12 shown in Figure 8 detects the first bit (A) of each of the bus selection control command C_{Ixx} and the data D_{xx}, determines whether the command contains the connection information among the slave chips (A=0) or does not (A=1), and selects the determination circuit 13 when the command contains the connection information, and selects the command bus selector circuit 14 when it does not. The remaining bits of the command and the data are used in the selected circuit. In this circuit selection, assume that the initial setting state is A=1. Therefore, unless the state becomes A=0, the command is outputted to the command bus selector circuit 14, while ignoring the destination selection circuit 12. The provision of the initial setting state can eliminate the need for the analysis in the determination circuit 13 for each command when commands are transmitted continuously to the command bus selector circuit 14. This realizes smooth command transmission. The analysis of each command will be described as follows with reference to Figures 12 and 13.

(1) When A=0

In Figure 8, the destination selection circuit 12 outputs a command to the determination circuit 13. In the determination circuit 13, the determination unit 132 analyzes the combination of the second and third bits (B, C) of this command, and generates a control command to be transmitted to the latch circuits 133a,

133b so as to control the transmission of the determination signal from the determination circuit 13 to one or both of the command bus selector circuit 14 and the data bus selector circuit 15.

5 The determination unit 132 of the determination circuit 13 analyzes the command to determine the fourth and fifth bits (D, E) and the sixth and seventh bits (F, G) of the command so as to generate a signal which controls the switching of at least one of the command bus selector circuit 14 and the data bus selector circuit 15.

(2) When A=1

The second to seventh bits of the command become the command for the selected slave chip. The division and combination of these bits and the bus width can be changed if necessary.

15 The behavior of the semiconductor integrated circuit system 110 will be described in detail as follows.

Figure 16 schematically shows as an example of the behavior of the semiconductor integrated circuit system 110 in Figure 8, the readout timing involving the transmission of commands from the master chip (CPU) 1 to the slave chips 2a, 2b and 2c (DRAM chips) via the command bus CB, the execution of the commands in the corresponding slave chips 2a to 2c, and the output of the obtained data to the master chip 1 via the data bus DB.

In Figure 16, CLK1 indicates a clock; the command bus CB and the data bus DB indicate the statuses of signals on the

command bus CB and the data bus DB shown in Figure 8; and SWa to SWf indicate the connection conditions of the selector switches SWa to SWf shown in Figures 11 (a) and 11 (b). Here, high and low mean ON and OFF, respectively.

5 First, at timing T1, the master chip 1 outputs the control command JC in order to make the determination circuit 13 shown in Figure 8 the destination of the command. Assume that all bits of the control command JC are "0". Since the first bit of this command is "0", the determination circuit 13 is selected
10 as the destination of the command, based on the determination results shown in Figure 13.

At timing T2, the master chip 1 outputs the command CI1 containing the connection information among the slave chips 2a to 2c, and the determination circuit 13 analyzes the command
15 CI1 to determine the bit values. The determination results in the determination circuit 13 indicate that the second and third bits of the command both have a value "1", so that the command bus selector circuit 14 and the data bus selector circuit 15 are both controlled. Since the fourth and fifth bits have
20 values "0" and "1", respectively, and the sixth and seventh bits have values "1" and "0", respectively, the determination circuit 13 generates and outputs the selector signals which make the switch SWa of the command bus selector circuit 14 and the switch SWe of the data bus selector circuit 15 both on.

25 By the selector signal outputted to make the switch SWa of the

command bus selector circuit 14 on, the connection of the command bus CB between the command bus selector circuit 14 and the slave chip 2a is established.

At timings T3 to T5, the master chip 1 transmits the commands Ca1 to Ca3 to the slave chip 2a. The command Ca1 whose first (most significant) bit is "1" passes through the destination selection circuit 12 on the command bus CB and is transferred to the command bus selector circuit 14 without being processed in the determination circuit 13. This is because the initial setting state in the destination selection circuit 12 is A=1. These operations make the command transmission highly efficient.

When the master chip 1 generates a request to transmit a command to the slave chip 2c, the master chip 1 again outputs the command JC to the destination selection circuit 12 via the command bus CB at timing T6 in order to change the connection of the destination selection circuit 12. As a result, the destination of the command is switched to the determination circuit 13. At timing T7, the master chip 1 transmits the command CI2 containing the connection information of the chips 1 and 2a to 2c to make the switch SWc on and the switch SWa off in the command bus selector circuit 14, thereby to switch the connection of the command bus CB.

At timings T8 to T10, the master chip 1 transmits the commands Cc1 to Cc3 to the slave chip 2c. At the same time, the master

chip 1 takes in the data Da1 to Da3 obtained in the slave chip 2a at timing T7 by making the switches SWd and SWe of the data bus selector circuit 15 on and off, respectively, so as to switch the connection of the data bus DB.

5 By the repetition of these operations, the master chip 1 and the slave chips 2a to 2c can transmit and receive command and data to and from each other. When it is desired to transmit a command or to take data in, the master chip 1 can transmit the control command JC and the command containing the connection information to switch the connection of the bus, thereby to control the transmission of commands and data to and from the slave chips 2a to 2c.

EMBODIMENT 3

15 Figure 14 is a block diagram showing the semiconductor integrated circuit system 111 of the third embodiment of the present invention.

The feature of the present embodiment is that the master chip 1 and the bus selector device 3b are connected with each other via a control bus EB which is a connection information bus designed specifically to carry the command containing connection information among the chips 1 and 2a to 2c.

As shown in Figure 14, the master chip 1 and the bus selector device 3b are connected with each other via a command bus CB and a data bus DB each having a width of plural bits to carry

commands and data, and also via the control bus EB having a width of plural bits to carry the command containing the connection information among the chips 1 and 2a to 2c. Similarly, the slave chips 2a to 2c and the bus selector device 3b are connected with each other via the command buses CBa to CBc and the data buses DBa to DBc to carry commands and data.

In Figure 14, the bus selector device 3b comprises input/output units 4 and 18 which transmit and receive commands via the command bus CB and the control bus EB, respectively, each of which is composed of a transmission path having a width of plural bits; a determination circuit (determination means) 132 which receives the commands from the input/output unit 18, analyzes the connection information among the chips 1 and 2a to 2c to determine the bit values, and outputs the determined results; a command bus selector circuit 142 arranged on a point of intersection of the command buses CB and CBa to CBc which connect the master chip 1 and the slave chips 2a to 2c; and a data bus selector circuit 152 arranged on a point of intersection of the data buses DB and DBa to DBc which connect the master chip 1 and the slave chips 2a to 2c. The command bus selector circuit 142 and the data bus selector circuit 152 receive the determination results from the determination circuit 132, switch the connection of the command buses and the data buses, based on the determination results, and connect the master chip 1 with the slave chips 2a to 2c, and the slave

chips 2a to 2c themselves.

In addition to the above-mentioned input/output unit (control command input means) 4 which transmits and receives commands (control commands) to control the slave chips 2a to 2c to and from the master chip 1 via the command bus CB and the input/output unit 18 which transmits and receives commands (hereinafter referred to as connection commands) containing connection information among the chips 1 and 2a to 2c to and from the master chip 1 via the control bus EB, the bus selector device 3b further comprises input/output units (control command output means) 6, 8 and 10 which receive the control commands from the master chip 1 and output them via the command bus selector circuit 142 to the slave chips 2a to 2c; input/output units (data input means and data output means) 7, 9 and 11 which transmit and receive data outputted from the slave chips 2a to 2c to and from the selector circuit 152 via the data buses DBa to DBc; and an input/output unit (data output means) 5 which receives data from the slave chips 2a to 2c through the data bus selector circuit 152 and transmits the data to the master chip 1 via the data bus DB.

As mentioned above, the command bus selector circuit 142 and the data bus selector circuit 152 are arranged on a point of intersection of the command buses CB and CBa to CBc and on a point of intersection of the data buses DB and DBa to DBc, respectively, which connect the master chip 1 and the slave

chips 2a to 2c. However, the arrangement of the two circuits is not restricted to the one used in the present embodiment. For example, beside the point of intersection of the command buses and the point of intersection of the data buses, additional selector circuits could be arranged on each point of intersection of the command buses and the data buses. This structure enables the chips 1 and 2a to 2c share commands and data with each other as described in the second embodiment.

The determination circuit 132, the command bus selector circuit 142 and the data bus selector circuit 152 shown in Figure 14 have the same structures as the determination circuit 13, the command bus selector circuit 14 and the data bus selector circuit 15 shown in the second embodiment.

Before the description of the behavior of the semiconductor integrated circuit system 111, the structure of the command packet involved in the behavior of the system 111 will be described as follows.

Figure 15 shows a rough structure of the command packet containing connection information among the chips used in the present embodiment. Assume that the control bus EB which carries a command has a bus width of 6 bits. The command buses CB and CBa to CBc and the data buses DB and DBa to DBc each have a bus width of n bits (n is an arbitrary value).

The structure of the command packet will be described as

follows with reference to Figure 15. The determination unit 132 determines the combination of the first and second bits (A, B) of the command, and generates a control command to control the latch circuits 133a, 133b thereby to select between the command bus selector circuit 142 and the data bus selector circuit 152 as the destination of the determination signal outputted from the determination circuit 13. The determination unit 132 also analyzes the third and fourth bits (C, D) and the fifth and sixth bits (E, F) of the command to determine their values, and generates a selector signal which selects at least one of these circuits 142, 152. The combination and contents of the values of the first through sixth bits are not described here again because they are identical to those shown in Figure 13 in the second embodiment. The division and combination of these bits and the bus width can be changed if necessary.

The behavior of the semiconductor integrated circuit system 111 will be described in detail as follows.

Figure 17 schematically shows as an example of the behavior of the semiconductor integrated circuit system 111 in Figure 14, the readout timing involving the transmission of commands from the master chip (CPU) 1 to the slave chips 2a, 2b and 2c (DRAM chips) via the command bus CB, the execution of the commands in the corresponding slave chips 2a to 2c and the output of the obtained data to the master chip 1 via the data bus DC.

The master chip 1 transmits the command containing the connection information among the chips 1 and 2a to 2c to the bus selector device 3b via the control bus EB.

In Figure 17, CLK1 indicates a clock; the command bus CB, the data bus DB and the control bus EB indicate the statuses of signals on the command bus CB, the data bus DB and the control bus EB; and SWa to SWf indicate the connection conditions of the selector switches SWa to SWf shown in Figures 11 (a) and 11 (b).

First, as for the operations at timings T1 to T4, assume that the command buses CB and CBa between the master chip 1 and the slave chip 2a are connected by the selector signal of the determination circuit 132. The commands C1 to C4 existing on the command bus CB in this condition are transmitted from the master chip 1 to the slave chip 2a via the command buses CB and CBa.

When generating a command transmission request to the slave chip 2b, the master chip 1 transmits the commands Ib1, Id1 (refer to Figure 15) containing the connection information among the chips 1 and 2a to 2c to the determination circuit 132 via the control bus EB at timings T4 and T5 in order to establish each connection of the command bus CBb to the slave chip 2b and of the data bus DBa to the slave chip 2a. The determination circuit 132 analyzes the commands Ib1 and Id1, and outputs the selector signals to the command bus selector circuit 14 and the data

bus selector circuit 15. At timing T5, the master chip 1 makes the switches SWa and SWb shown in Figure 11 (a) off and on, respectively, to establish the connection of the command buses CB and CBb between the master chip 1 and the slave chip 2b.

5 At timing T6, the master chip 1 makes the switches SWf and SWd shown in Figure 11 (b) off and on, respectively, to establish the connection of the data buses DB and DBa between the master chip 1 and the slave chip 2a.

10 At timings T6 to T9, the master chip 1 shown in Figure 14 outputs the commands C5 to C8 to the slave chip 2b via the command bus CB. At timings T7 to T10, the master chip 1 takes in the data D1 to D4 from the slave chip 2a via the data bus DB.

15 By the repetition of these operations, the master chip 1 can transmit and receive command and data to and from the slave chips 2a to 2c, while switching the bus connections. When it is desired to transmit a command or to receive data, the master chip 1 can transmit the command containing the connection information to control the transmission of commands and data between the master chip 1 and the slave chips 2a to 2c.

20 Figure 19 schematically shows as an example of the behavior of the semiconductor integrated circuit system 111 shown in Figure 14, the timing when the master chip (CPU) 1 transmits commands to the slave chips 2a, 2b and 2c (DRAM chips) via the command bus CB, while the slave chip 2a is outputting data to
25 the master chip 1 via the data bus DC. The master chip 1 also

transmits the command containing the connection information among the chips 1 and 2a to 2c to the bus selector device 3b via the control bus EB..

First, as for the operations at timings T1 to T4, assume
5 that the command buses CB and CBa between the master chip 1 and the slave chip 2a are connected by a selector signal from the determination circuit 132. The commands C1 to C4 existing on the command bus CB in this condition are transmitted from the master chip 1 to the slave chip 2a.

At timing T4, the master chip 1 outputs the command Ia1
10 which makes the switch SWa off via the control bus EB. At timing T5, the master chip 1 outputs the command Id1 via the control bus EB in order to connect the data buses DBa and DB. After the establishment of the bus connection, the slave chip 2a outputs
15 the data D1 to D14 to the master chip 1 via the data bus DB. During this transmission, the status of the selector switch SWd is held by the latch circuit 133b. At timing T6, the master chip 1 outputs the command Ib1 on the control bus EB to make the switch SWb on, thereby to establish the connection between
20 the command buses CB and CBb.

At timings T8 and T9, the master chip 1 outputs the commands C5 and C6 to the slave chip 2b. At the same timing T9, the master chip 1 outputs the command IB2 via the control bus EB in order to disconnect the connection between the command buses
25 CB and CBb.

At timing T10, the master chip 1 outputs the command Ic2 to the slave chip 2c via the control bus EB to establish the connection between the command buses CB and CBc. At timing T12 and the subsequent timings, the master chip 1 transmits the commands C7 to C15 to the slave chip 2c.

Through these operations, the master chip 1 can enter data continuously, while transmitting commands to the slave chips 2a to 2c.

Although it is not described in the present embodiment, not only the connection between the master chip 1 and the slave chips 2a to 2c but also the connection among the slave chips 2a to 2c themselves can be achieved by modifying the command bus selector circuit 142 and the data bus selector circuit 152 in such a manner as to arrange switches SW1 to SW14 on the command bus CB and the data bus DB as shown in Figure 18 and by transmitting the selector signals from the determination circuit 132 to control these switches SW1 to SW14.

For example, when the slave chips 2a to 2c shown in Figure 14 have a calculation function, the master chip 1 first outputs a command to connect the command buses CB and CBa to the determination circuit 132 via the control bus EB so as to establish the connection between the command buses CB and CBc. Later, the master chip 1 transmits a command to the slave chip 2c via the command buses CB and CBc. The slave chip 2c executes the command. Before the slave chip 2c outputs the data obtained

by the excursion of the command via the data bus DBc, the master chip 1 outputs a command which connects the data bus DBc and the command bus CBb to the determination circuit 132. The determination circuit 132 analyzes the command to determine the bit values, and outputs selector signals to make the switches SW7 and SW8 shown in Figure 18 on. As a result, the connection between the data bus DBc and the command bus CBb of the slave chips 2c and 2b is established to transmit data from the slave chip 2c to the slave chip 2b. Alternatively, the slave chip 2b can receive the data as a command to perform another process. Switching the bus connections in this manner can make the chips 1 and 2a to 2c share commands and data, which is effective for the execution of a program required plural processes.

EMBODIMENT 4

Figure 20 shows the fourth embodiment of the present invention. As shown in the drawing, the semiconductor integrated circuit system comprises a master chip 1, seven slave chips 2a to 2g, and a bus selector device 3c. Similar to the first to third embodiments, the bus selector device 3c is provided independently of the master chip 1 and arranged substantially at the same distance from the seven slave chips 2a to 2g and the master chip 1. Consequently, the buses Ba to Bg which connect the respective slave chips 2a to 2g and the bus selector device 3c, and the bus B which connects the master chip 1 and the bus

selector device 3c have approximately the same length and are shorter than those in the first to third embodiments.

In the present embodiment, signals transmitted among the buses have very few variations in transmission delay, which enables high-speed transmission of commands and data among the eight chips 1 and 2a to 2g.

As described hereinbefore, in the present invention, the bus selector device is provided independent of the master chip to reduce the number of pins in the master chip. Furthermore, the arrangement of the bus selector device can be freely determined, so that the device can be arranged substantially at the same distance from the slave chips to make the bus length from the master chip to each slave chip equal and short. As a result, data transmission among the master chip and the slave chips can be performed at high speed while storing large amounts of data in the slave chips.